The Influence of Stratospheric Intrusions of Ozone on Surface Concentrations

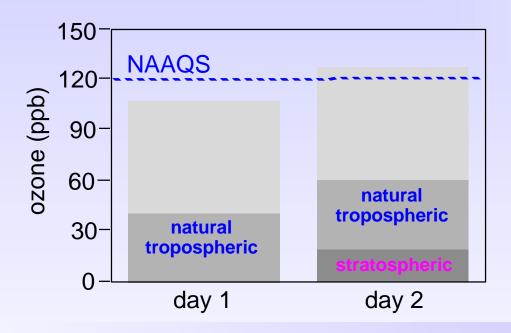
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Pacific Northwest National Laboratory

ACP Annual Science Meeting, 24 - 27 February 1997

Hypothesis

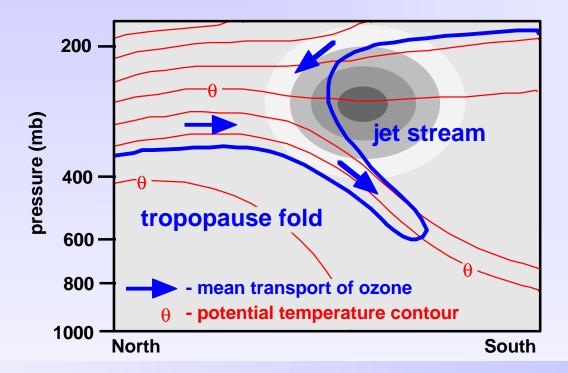
variations of mid-tropospheric ozone resulting from stratospheric intrusions frequently contribute to high surface ozone concentrations that exceed the NAAQS for ozone



Conceptual diagram depicting the impact of the introduction of **stratospheric** ozone on surface ozone concentrations, assuming that **anthropogenic** and **natural** ozone contributions remain the same from one day to the next.

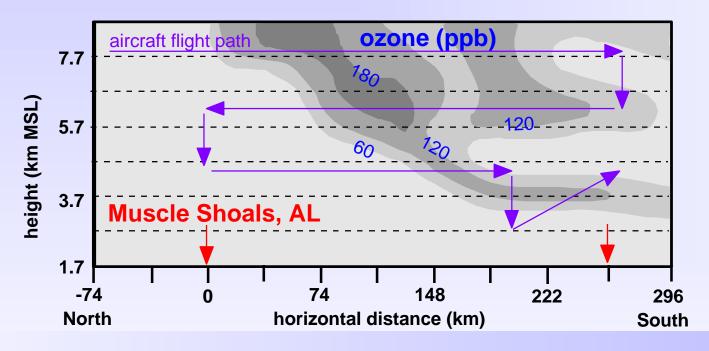
Stratospheric Intrusions of Ozone

conceptual diagram of a tropopause fold and the associated transport of ozone from the stratosphere to the mid troposphere



Observational Evidence

- concentration field based on aircraft measurements over the southern U.S. (Viezee et al. 1983)
- other examples of stratospheric intrusions of ozone can be found in the literature

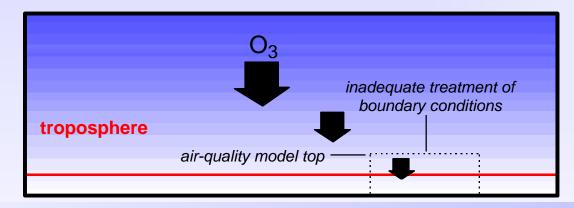


Principal Scientific Questions

- what are the combined synoptic, mesoscale, and boundary layer processes responsible for ozone transported and mixed into the lower troposphere?
- what are the relative contributions of stratospheric and tropospheric sources of ozone to the observed surface ozone concentrations?
- how frequently do stratospheric instrusions of ozone significantly increase ozone concentrations in the mid-troposphere and near the surface?
- what regions are more likely to be affected by stratospheric intrusions of ozone?

Relevance

- most air-quality modeling studies simply neglect the influence of stratospheric intrusions that may be responsible for regional variations in ozone concentrations near the surface
- stratospheric intrusions of ozone may complicate emission control strategies
- issue is of interest to NARSTO



Approach

- data analyses of chemical and meteorological measurements needed to find evidence of the possible influence of stratospheric ozone at the surface
- a series of photochemical modeling studies designed to simulate intrusions of stratospheric ozone and determine the relative contribution of ozone sources in the lower troposphere

Approach: Data

- meteorological fields from the NCEP/NCAR reanalysis archives
- **total column ozone from satellite measurements**
- ozone profiles from ozonesonde measurements
- surface ozone and ozone precursors from airquality monitoring stations

Existing observations will be used primarily, but we plan to take advantage of data collected by ACP field experiments in 1998 and 1999.

Approach: Data Analyses

- analyze potential vorticity (PV) fields from the NCEP/NCAR meteorological archives
- correlate meteorological variables, including PV, with available ozone data
- because stratospheric intrusions of ozone are episodic, obtain climatological information about their occurance
- estimate average downward fluxes of ozone
- identify stratospheric intrusions events for regional-scale model case studies

Approach: Models

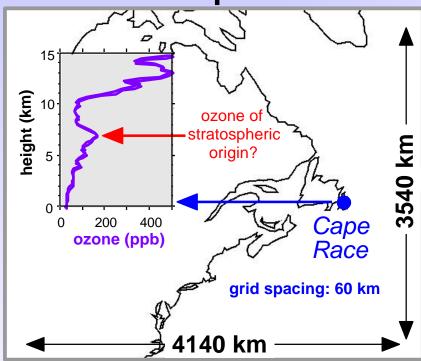
- Chemistry Model a limited-area version of PNNL's Global Chemistry Model (GChM) is used to simulate stratospheric intrusions of ozone as well as the natural and anthropogenic production of ozone
- Meteorological Model a nested mesoscale model (RAMS) with four-dimensional data assimilation will be used to provide high spatial and temporal resolution meteorological fields
- Lagrangian Particle Dispersion Model a particle model will be used to compute the trajectories of air parcels originating in the stratosphere

Approach: Modeling Studies

- modify GChM to include stratospheric chemistry
- several cases will be examined, based on previous data reported in the literature or evidence of instrusions obtained from the data analyses
- control simulations that include all processes
- sensitivity simulations that either systematically eliminate air chemistry processes or modify initial and lateral boundary conditions

Preliminary Case Study

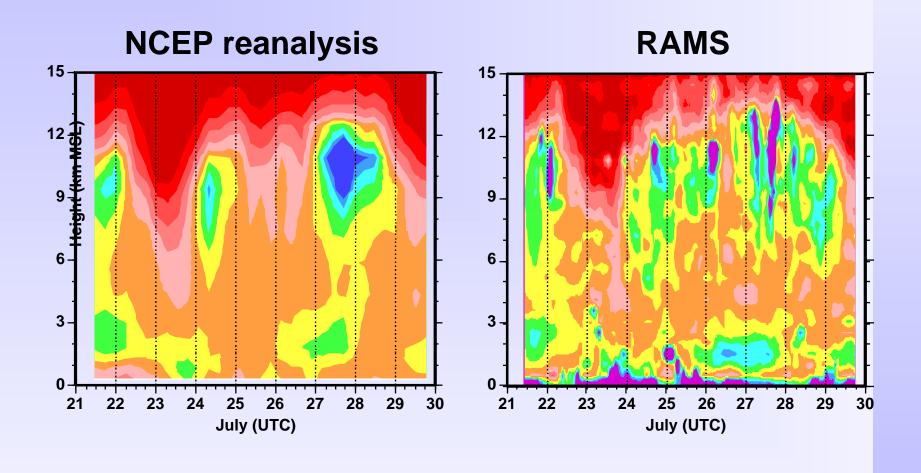
GChM / RAMS domain and model parameters



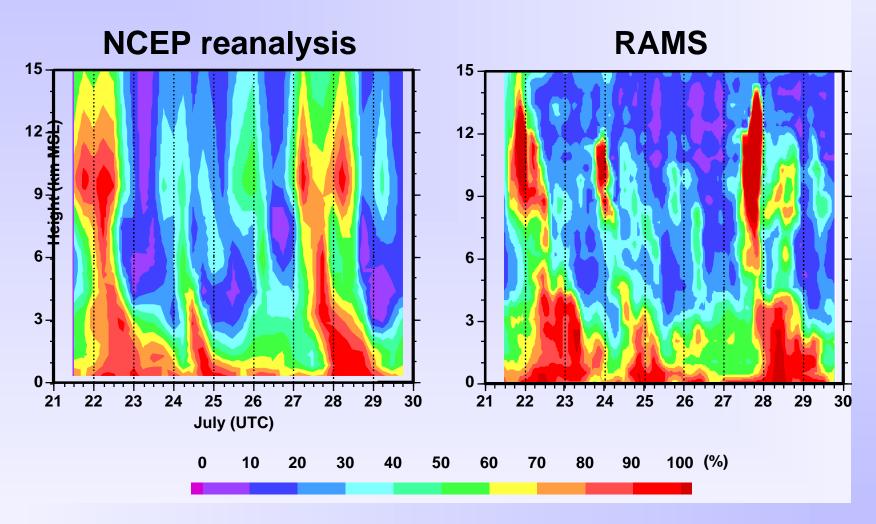
simulation period: 12 UTC July 21 - 18 UTC July 30

- July and 4 August, 1991 over Cape Race, Newfoundland suggest that stratospheric intrusions of ozone occurred
- GChM currently run with chemical production and emissions turned off to examine transport only
- predicted ozone compared with observations
- model results used to examine meteorological mechanisms associated with the intrusions

Potential Vorticity over Cape Race



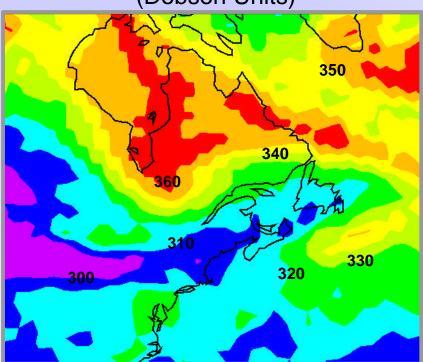
Relative Humidity over Cape Race



Total Ozone on 21 July 1991

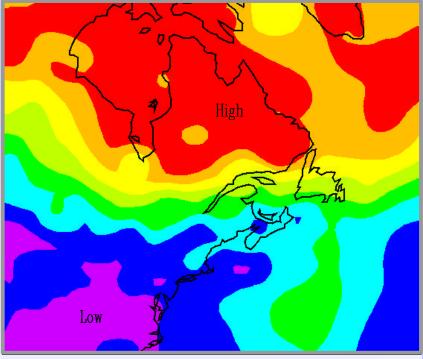
Observed TOMS Ozone

(Dobson Units)



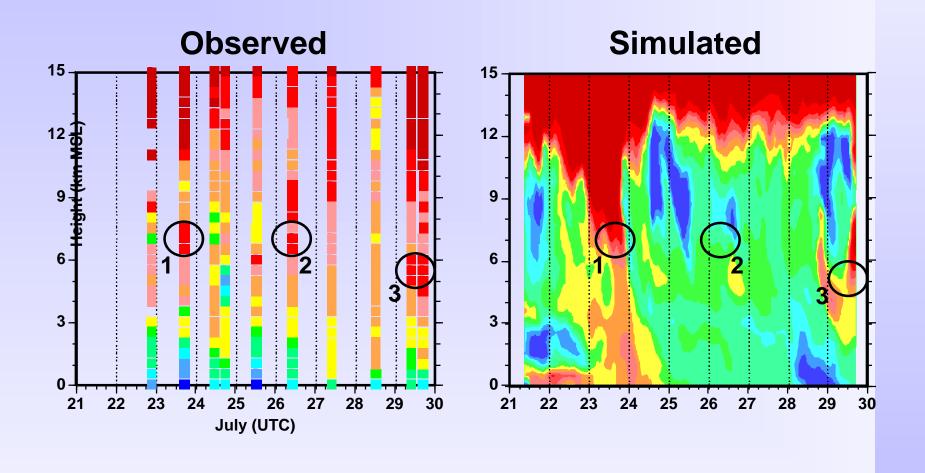
Derived Ozone

(ppb)



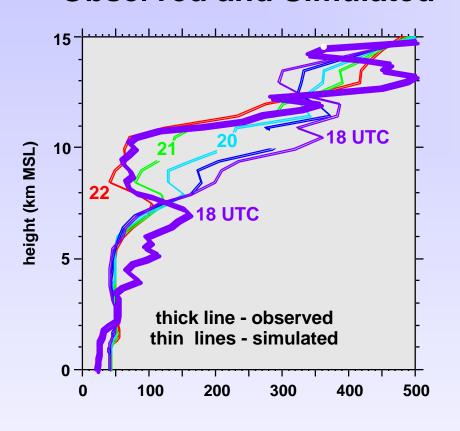
- based on NCEP PV fields at 12 UTC
- initial conditions employed by GChM

Ozone Profiles over Cape Race



Ozone Profiles on 23 July 1991

Observed and Simulated



- simulated ozone profiles are instantaneous values obtained at the grid point closest to Cape Race, Newfoundland
- simulated ozone profiles at 21 and 22 UTC in better agreement with the observed profile
- simulated peak ozone mixing ratio at 7.5 km at about the same height as observed peak
- large temporal variation in ozone due to the passage of the stratospheric intrusion

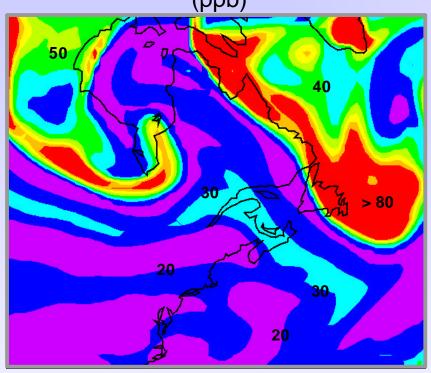
Ozone and PV on 23 July 1991

Ozone Mixing Ratio

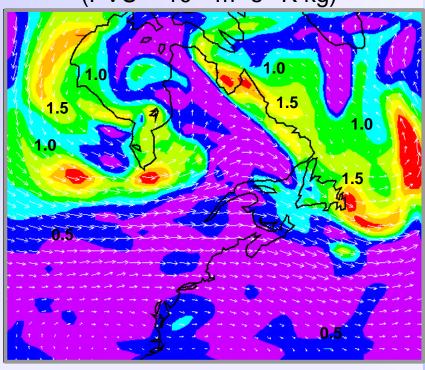
(ppb)

Potential Vorticity

 $(PVU = 10^{-6} \text{ m}^2 \text{ s}^{-1} \text{ K kg})$

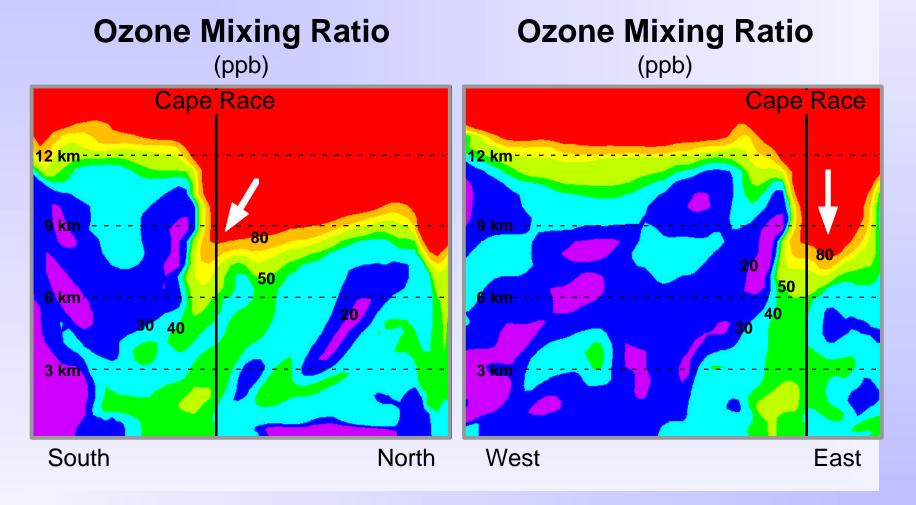


at 18 UTC and ~ 8 km MSL

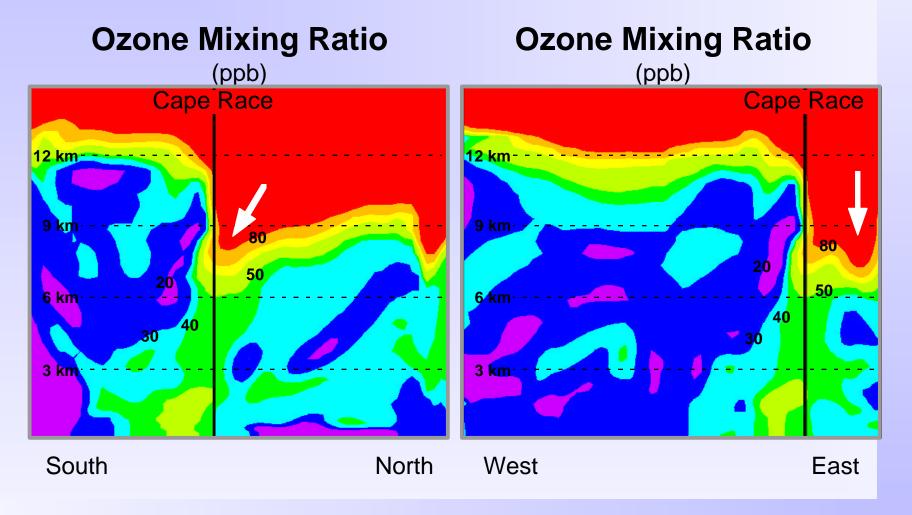


at 18 UTC and ~ 8 km MSL

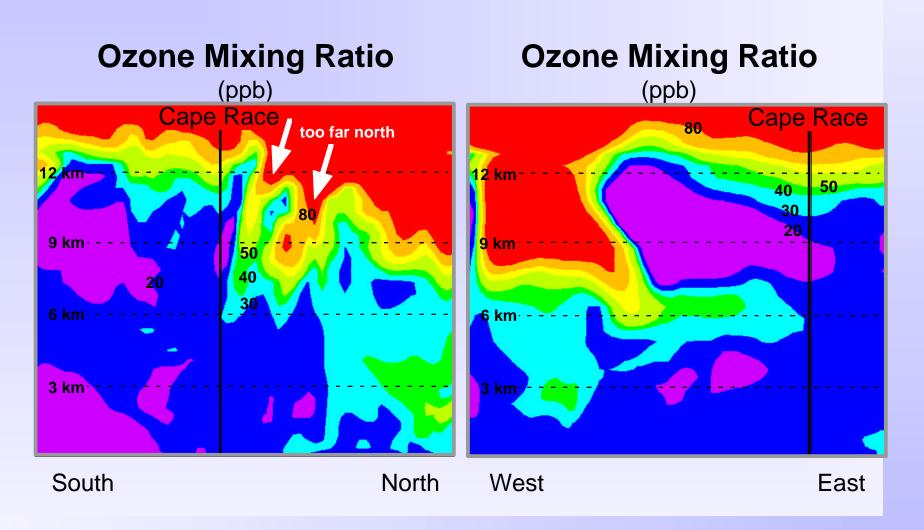
Intrusion Event 1 - 18 UTC 23 July



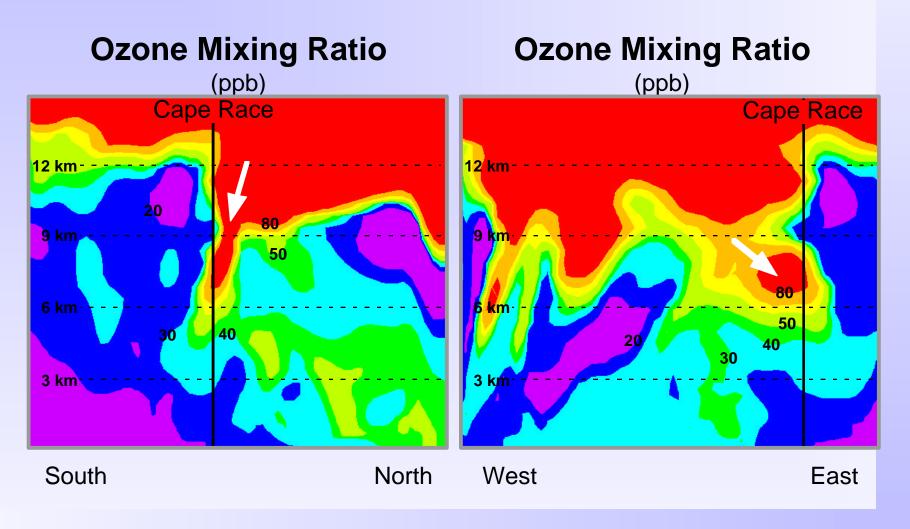
Intrusion Event 1 - 21 UTC 23 July



Intrusion Event 2 - 12 UTC 26 July



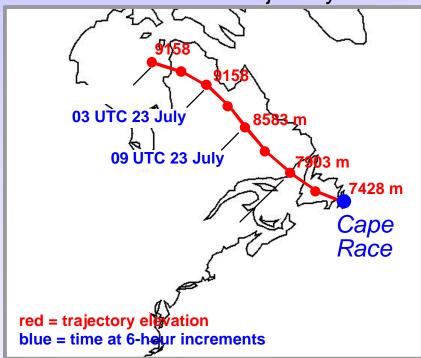
Intrusion Event 3 - 18 UTC 29 July



Trajectories

Intrusion Event 1

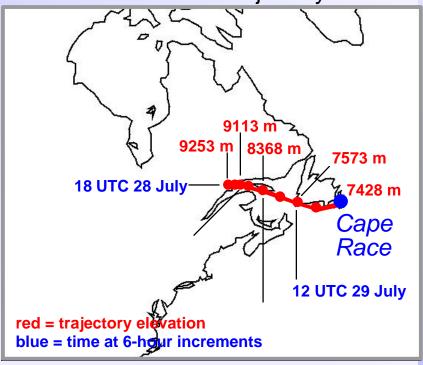
24-hour back trajectory



21 UTC 23 July

Intrusion Event 3

24-hour back trajectory



18 UTC 29 July

Summary of Preliminary Case Study

- encouraging results obtained the GChM / RAMS modeling system results suggest that peak ozone concentrations in the mid-troposphere over Cape Race are due to stratospheric intrusions of ozone
- differences between observed and simulated ozone profiles suggest some improvements are necessary before applying the model to other cases
- differences may be due to horizontal resolution, initial conditions, and lateral boundary conditions
- four-dimensional data assimilation will be employed to reduce errors associated with transport